White River Benthic Algae Study

2018 Summary

Presented by Michael R. Stevens and Natalie K. Day

U.S. Geological Survey

USGS
science for a changing world

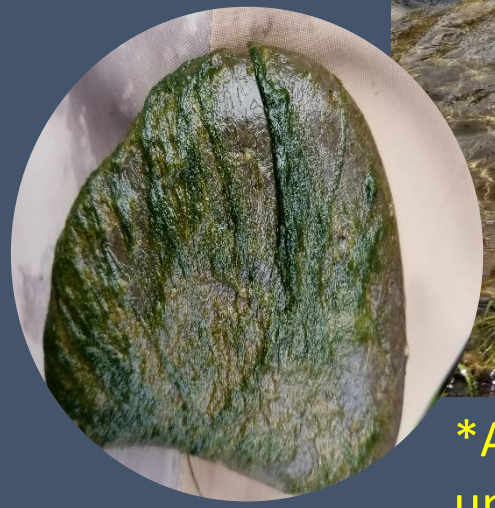
Acknowledgments

White River and Douglas Creek Conservation District
Rio Blanco County
Rio Blanco Water Conservancy District
Colorado River Water Conservation District
Town of Meeker/Meeker Sanitation District
Town of Rangely
Colorado Parks and Wildlife
Bureau of Land Management
U.S. Forest Service
Natural Resources Conservation Services
Trout Unlimited
Private Funding Partners
Landowners/Land managers
Other members of the local water community

USGS
science for a changing world

Presentation Outline

- Study Objectives
- 2018 Work-Plan Element
  - Site Locations (CPW, USGS)
- Status of Work
  - Results (preliminary)
  - Next Steps



*All photos and illustrations by USGS unless otherwise referenced.

USGS
science for a changing world

2018 - 2021 Study Objectives

The objective of the study is to document and understand benthic algal occurrence, characteristics, and controls at multiple locations within the White River study area. Specific objectives include:

1. Conduct data mining and historical synthesis of information relevant to the timing and occurrence of nuisance algal blooms in the White River Basin

2. Develop a better understanding of physical and chemical properties controlling algal growth in the Upper White River Basin

USGS
science for a changing world

2018 Work-Plan Elements

- Stream-Hydraulic/Channel Characteristics
  - Peak-Flow Measurements:
    - - Stream Velocity - Sediment Acoustics - Streambed-Particle Size
      - High-Water Marks - Cross-Section Geometry
- Historical Analysis
  - Water-Quality Trends:
    - - Nutrients (Nitrogen and Phosphorus species)
      - Specific Conductance - pH - Water Temperature - Streamflow
  - Literature Review
- Water Quality
  - Nutrient Probe Reconnaissance
  - Continuous QW monitoring: - Dissolved Oxygen and Water Temperature
  - Algae Sampling: - Chlorophyll-*a*/Ash-Free Dry Mass
  - Water Isotope Sampling: - Nitrogen and Oxygen isotopes of nitrate

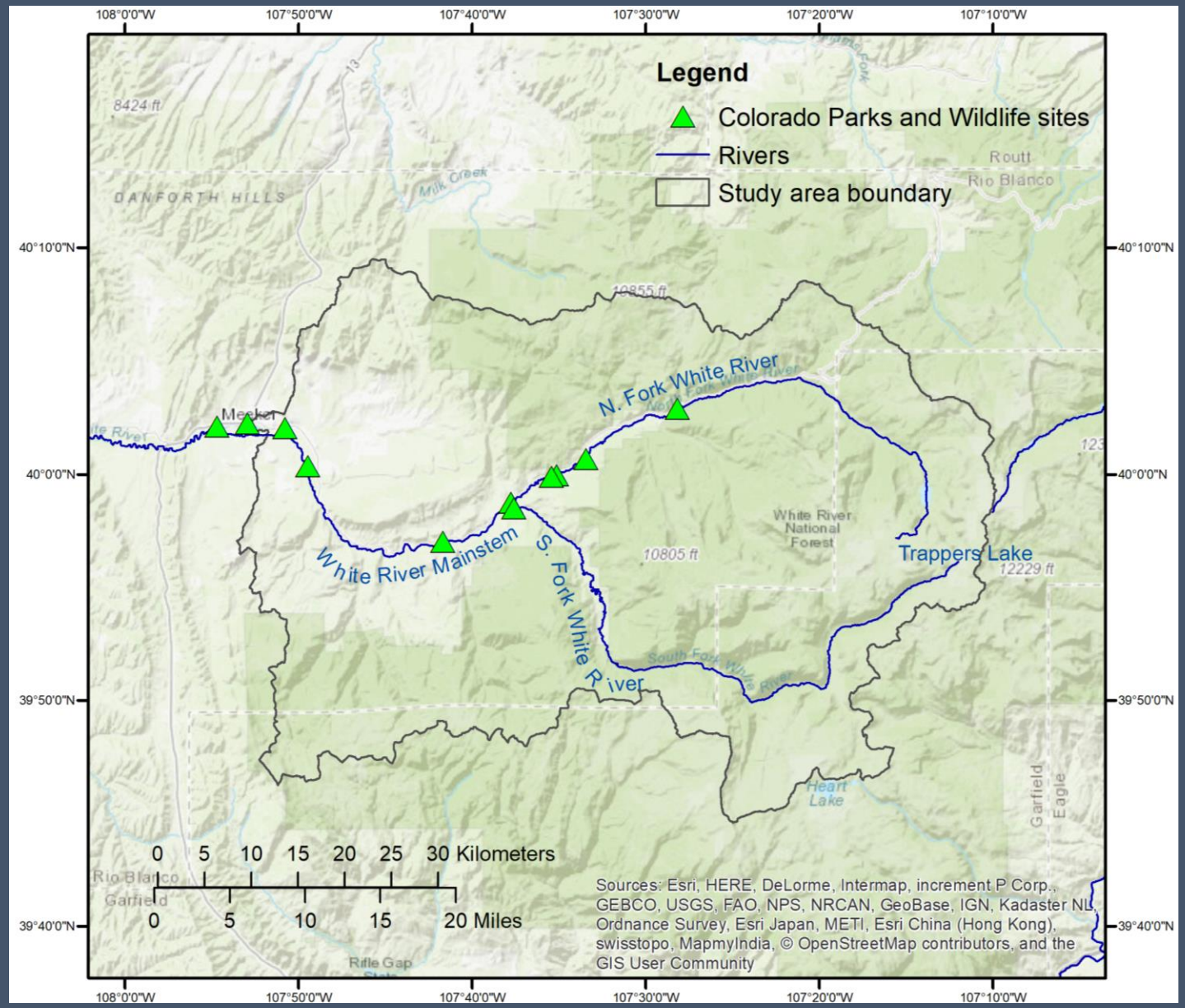
USGS
science for a changing world

Site Locations in Upper White River Basin

- **Colorado Parks and Wildlife**
  - **Annual Algae sampling**
  - **2015-present**

- U.S. Geological Survey Activities (current)
  - Quarterly Water-Quality
  - Streamflow Gages
  - Continuous WT

- Algae Study Sites
  - Selected 23 initial locations
  - 20 were selected
  - 1 site withdrawn during field season
  - 2018-2021



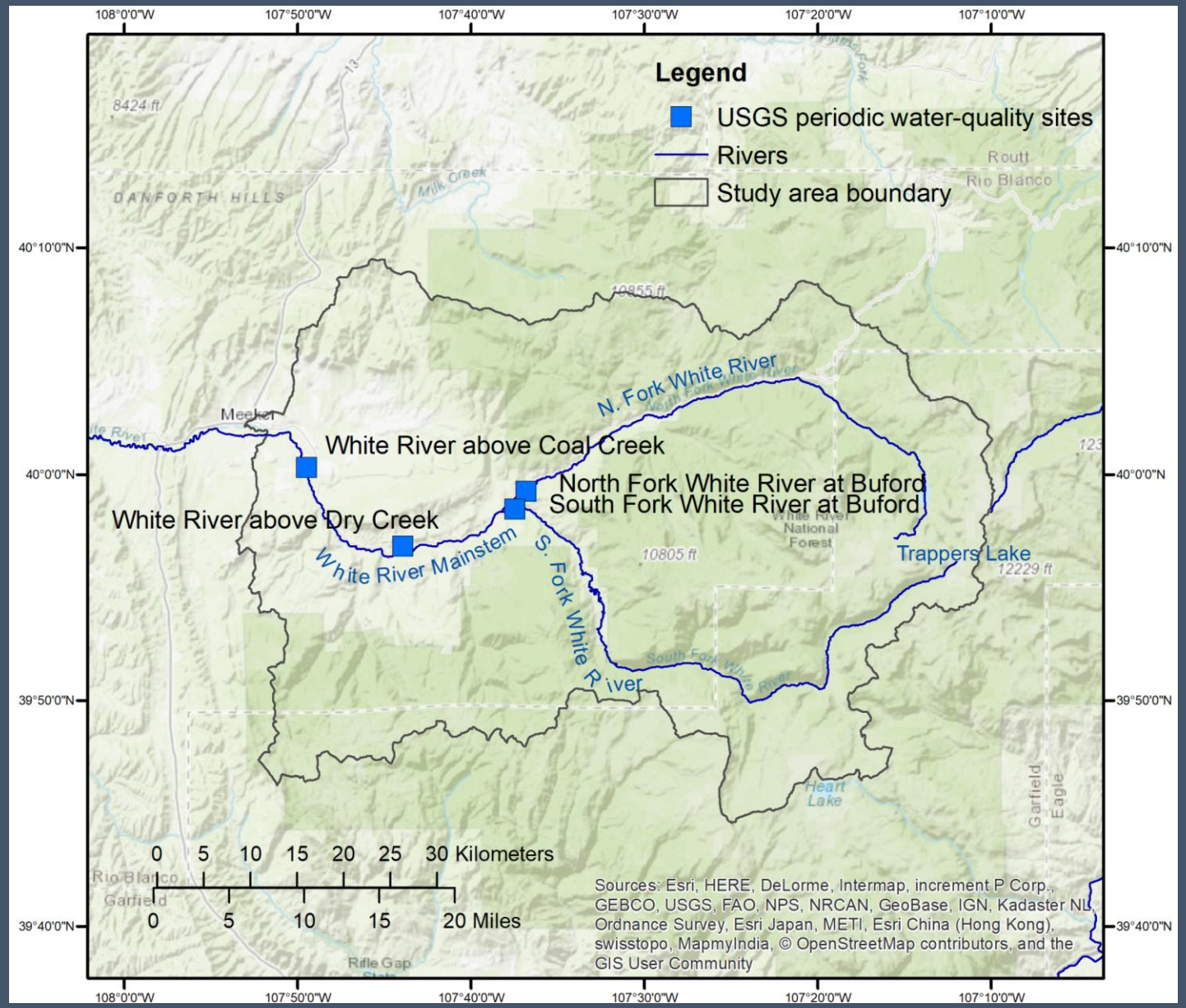
USGS
science for a changing world

Site Locations in Upper White River Basin

- Colorado Parks and Wildlife
  - Annual Algae sampling
  - 2015-present

- **U.S. Geological Survey Activities (current)**
  - **Quarterly Water-Quality**
  - **Streamflow Gages**
  - **Continuous WT**

- Algae Study Sites
  - Selected 23 initial locations
  - 20 were selected
  - 1 site withdrawn during field season
  - 2018-2021



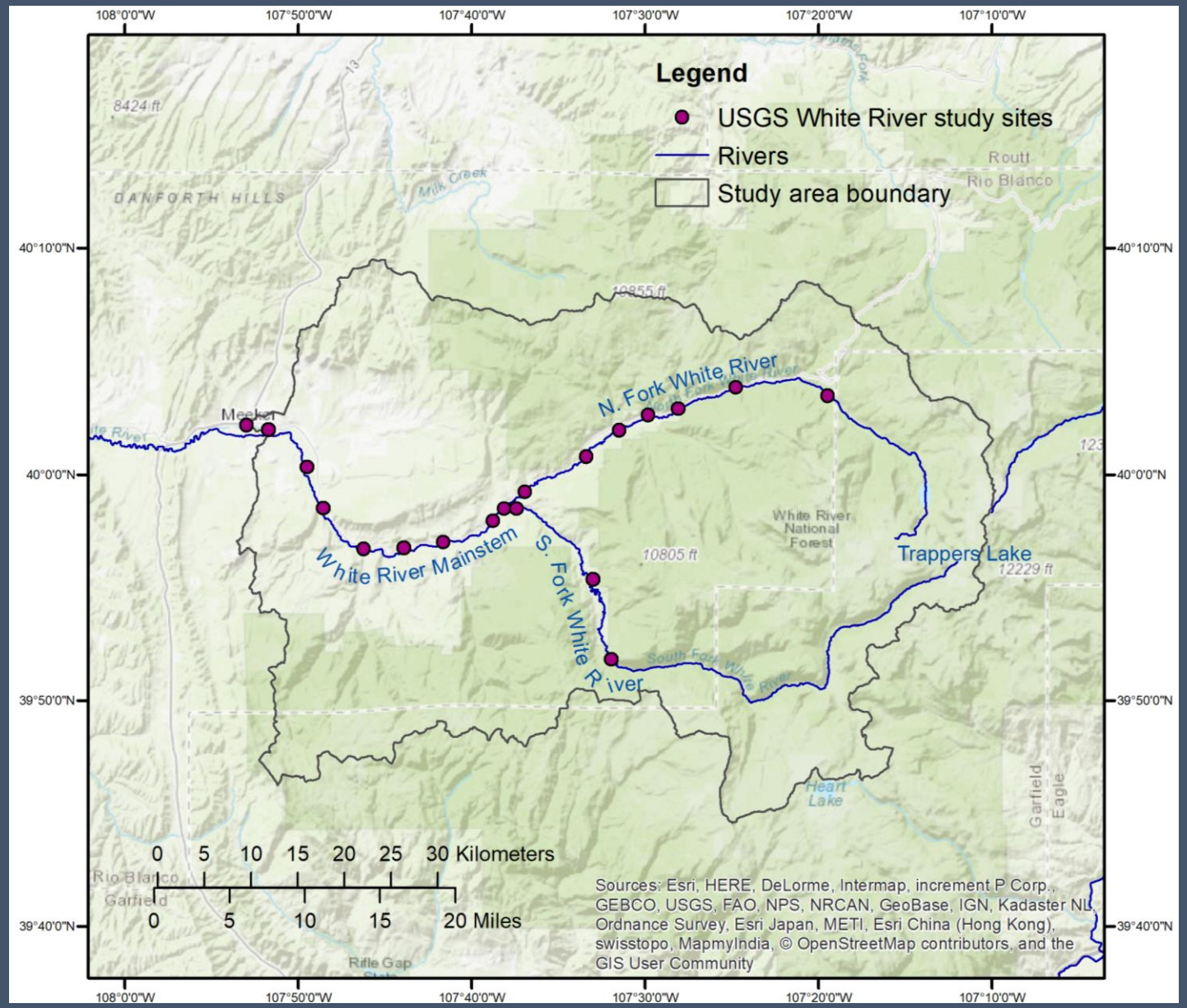
USGS
science for a changing world

Site Locations in Upper White River Basin

- Colorado Parks and Wildlife
  - Annual Algae sampling
  - 2015-present

- U.S. Geological Survey Activities (current)
  - Quarterly Water-Quality
  - Streamflow Gages
  - Continuous WT

- **Algae Study Sites**
  - **Selected 23 initial locations**
  - **20 were selected**
  - **1 site withdrawn during field season**
  - **2018-2021**



USGS
science for a changing world

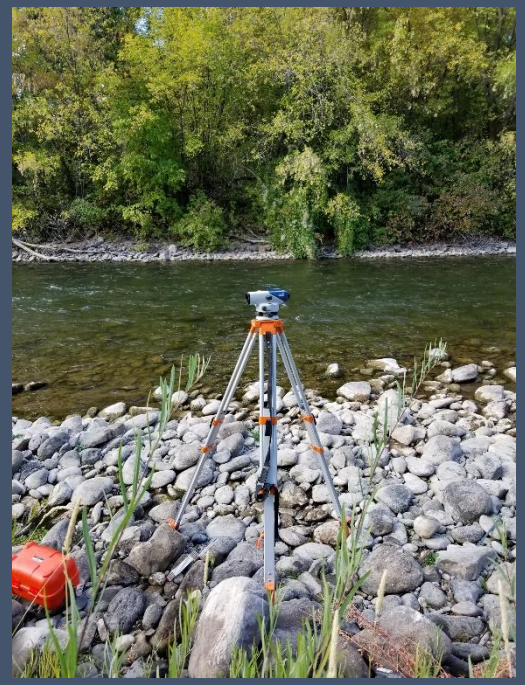
Stream-Hydraulic/Channel Characteristics

- Streamflow velocity and the mobility of the streambed can act as controls on algae growth
- Influences on productivity and the timing of algal blooms on the stream substrate
  - Substantial movement of streambed particles may abrade algal mats, suppressing or delaying algal-growth after spring runoff
  - Channel characteristics influence water temperature, nutrient cycling, and light availability which affect algal growth
- 2018 is the first year of measurements and data collection, additional peak flow velocity and hydrophone measurements planned in subsequent years

USGS
science for a changing world

Peak-Flow Measurements

- Bed-material movement may abrade algae, may kill macro-invertebrate grazers that control algal growth, and/or may re-suspend and flush nutrients from bed sediments
- Hydraulic analysis of streambed movement relies on three lines of evidence: stream velocity, sediment acoustics, and high-water marks/cross-section surveys
- Data were collected at 19 sites during high flow
- Limited runoff in spring 2018 provided a good opportunity to characterize the lower range of peak-flow mobility potential at each site



USGS
science for a changing world

Streambed particle-size analysis 2018

- Streambed movement is dependent on particle size, orientation, and embeddedness
- At each site, 300 streambed-particles (gravel, cobble, boulder, etc.) were measured
- Collected data will be used in critical flow analysis and then a part of the statistical analysis of other physical and chemical factors that influence algae
- Movement of large particles (cobbles and boulders) probably minimal in 2018

USGS
science for a changing world

Historical Analysis

- Recent reports by the Colorado Parks and Wildlife (2016) and Hydrosolutions (2017) suggest several factors may control algal growth
- Historical data was used to find indications of time trends in streamflow and water-quality (primarily nutrients) as well as possible source locations for nutrients
- Weighted Regressions on Time Discharge and Season model (Hirsch and others, 2010; and Hirsch and De Cicco, 2015) to assess seasonal and streamflow trends
- Synthesis of historical data and relevant studies informed objectives and approaches for this study

Hirsch, R.M., D.L. Moyer, and S.A. Archfield, 2010, Weighted Regressions on Time, Discharge, and Season (WRTDS), with an application to Chesapeake Bay River inputs: Journal of American Water Resources Association, vol 46, no. 5, 857-880 p.

Hirsch, R.M., and De Cicco, L.A., 2015, User guide to Exploration and Graphics for RivEr T rends (EGRET) and dataRetrieval: R packages for hydrologic data (version 2.0, February 2015): U.S. Geological Survey Techniques and Methods book 4, chap. A10, 93 p., https://dx.doi.org/10.3133/tm4A10. ISSN 2328-7055 (online)

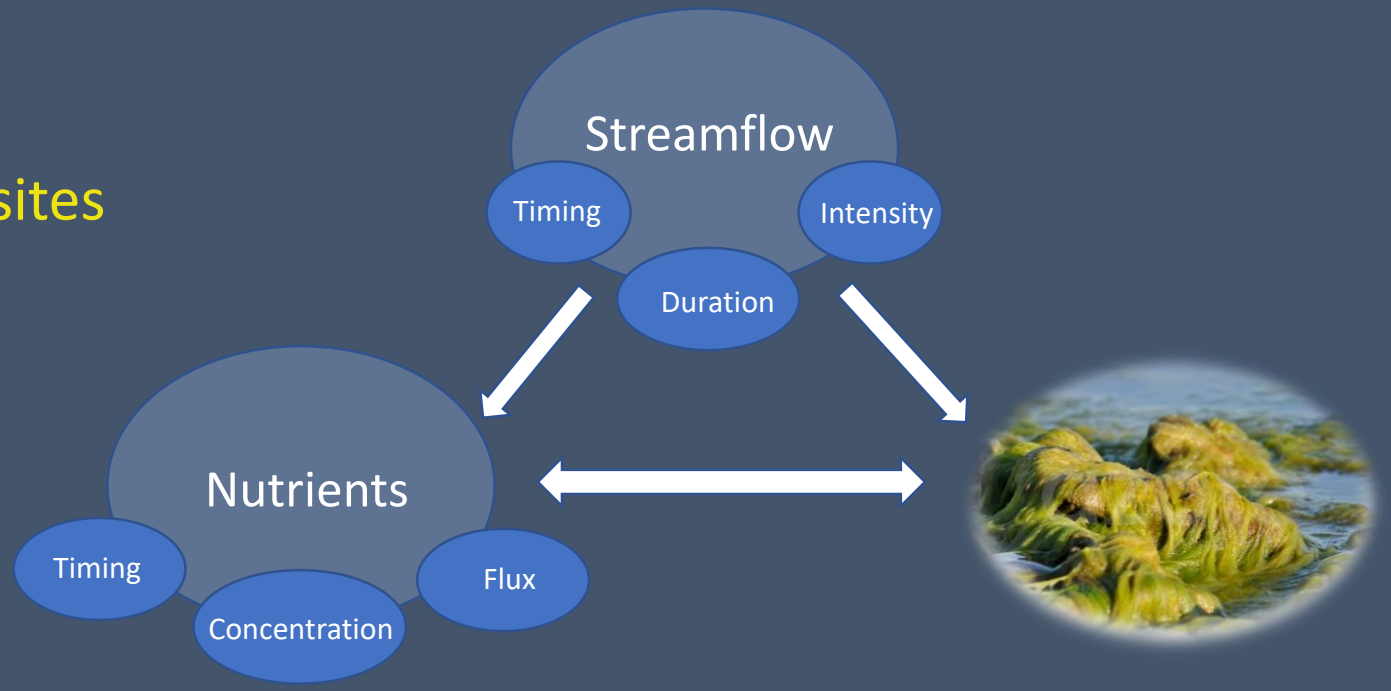
Hydrosolutions, 2017, Upper White River Watershed Assessment- DRAFT report, Prepared for: Elk Creek Ranch, 97p. plus Appendices.

May, M., 2016, White River Algae Report: Colorado Parks and Wildlife, 22p.

USGS
science for a changing world

Water-Quality Trends (Preliminary)

- To help provide answers about sources of nutrients and timing of change we looked at multiple variables:
  - Trends adjusted for variability due to streamflow and season
  - Timing of nutrient trends
  - Comparison of trends among sites
  - Streamflow statistics



USGS
science for a changing world

Water-Quality Methods

Analyzing flow-adjusted nutrient trends using the WRTDS method requires:

- Continuous discharge record
- Nutrient data representing all seasons and discharge records

We evaluated flow-adjusted nutrient trends in concentration and flux at four sites:

- North Fork White River at Buford
- South Fork White River at Buford
- White River above Coal Creek
- White River below Meeker

USGS
science for a changing world

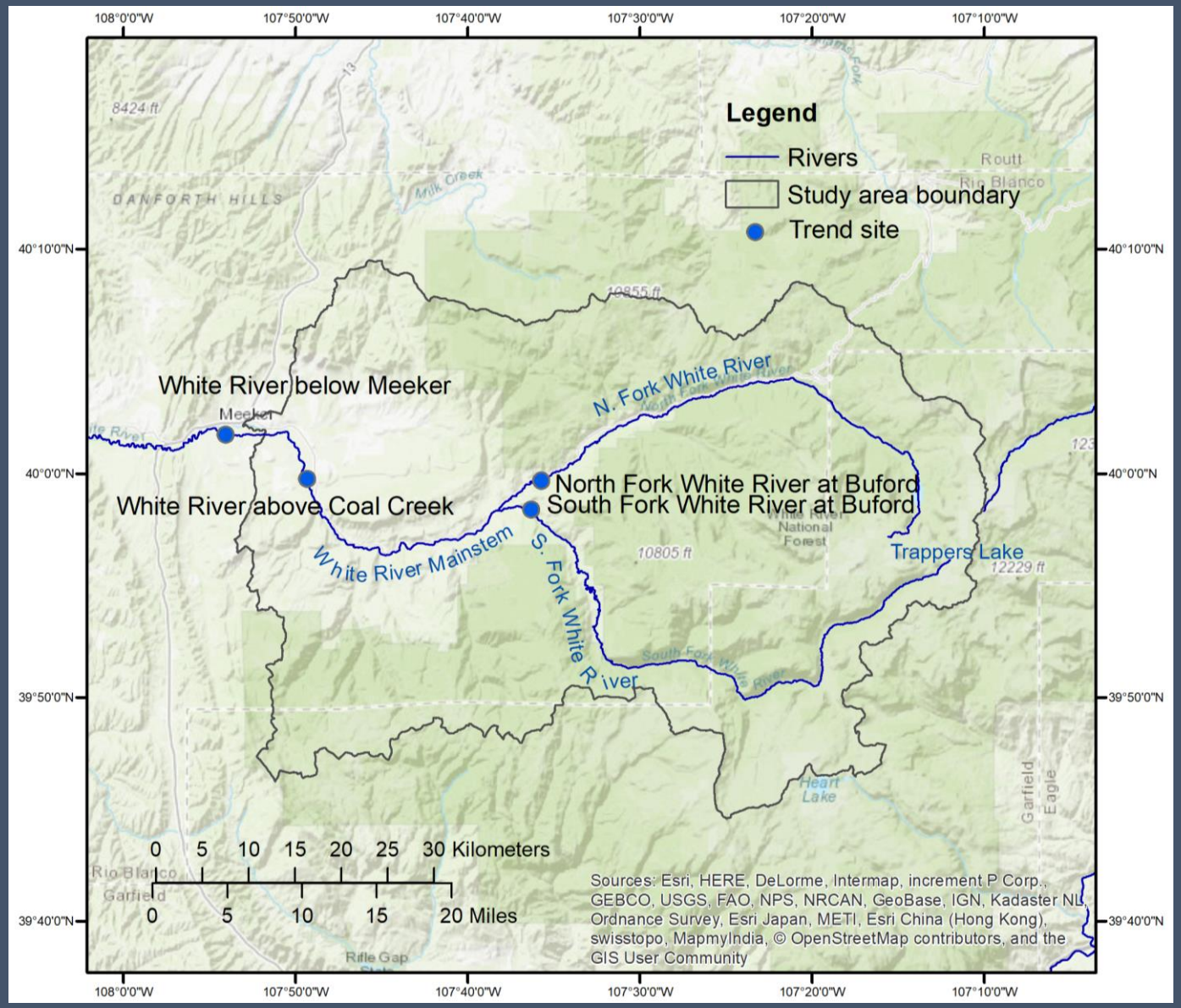
Trend Site Locations

White River above Coal Creek and White River below Meeker have continuous discharge record

North Fork and South Fork records estimated using Move.2 analysis (Lorenz, in-preparation)

Period of analysis 1999-2017

Kjeldahl Nitrogen and Total Phosphorus

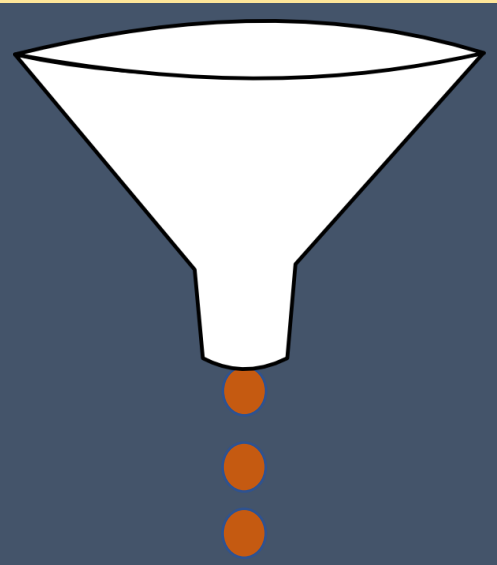


Lorenz, D.L., in preparation, smwrStats-An R package for the analysis of hydrologic data, Version 0.7.5: U.S. Geological Survey Open File Report.

USGS science for a changing world

Water-Quality Concepts

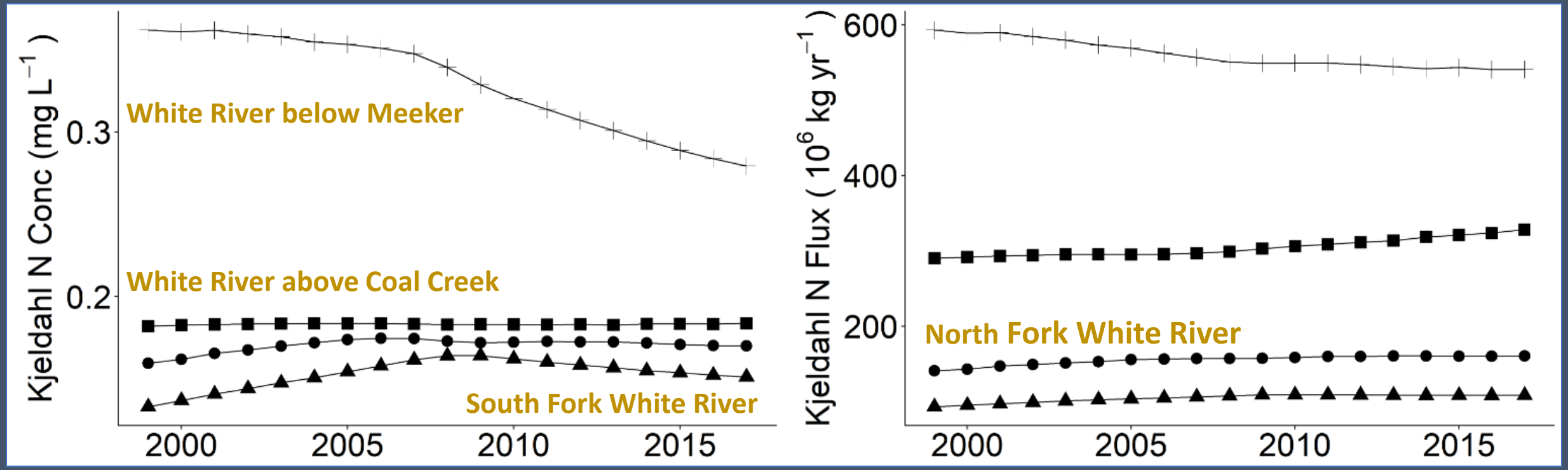
CONCENTRATION	FLUX
The amount of nutrient measured in a unit volume of water	The total amount of nutrient delivered downstream over a period of time



mg/L	**kg/yr**
Milligrams per liter	Kilograms per year

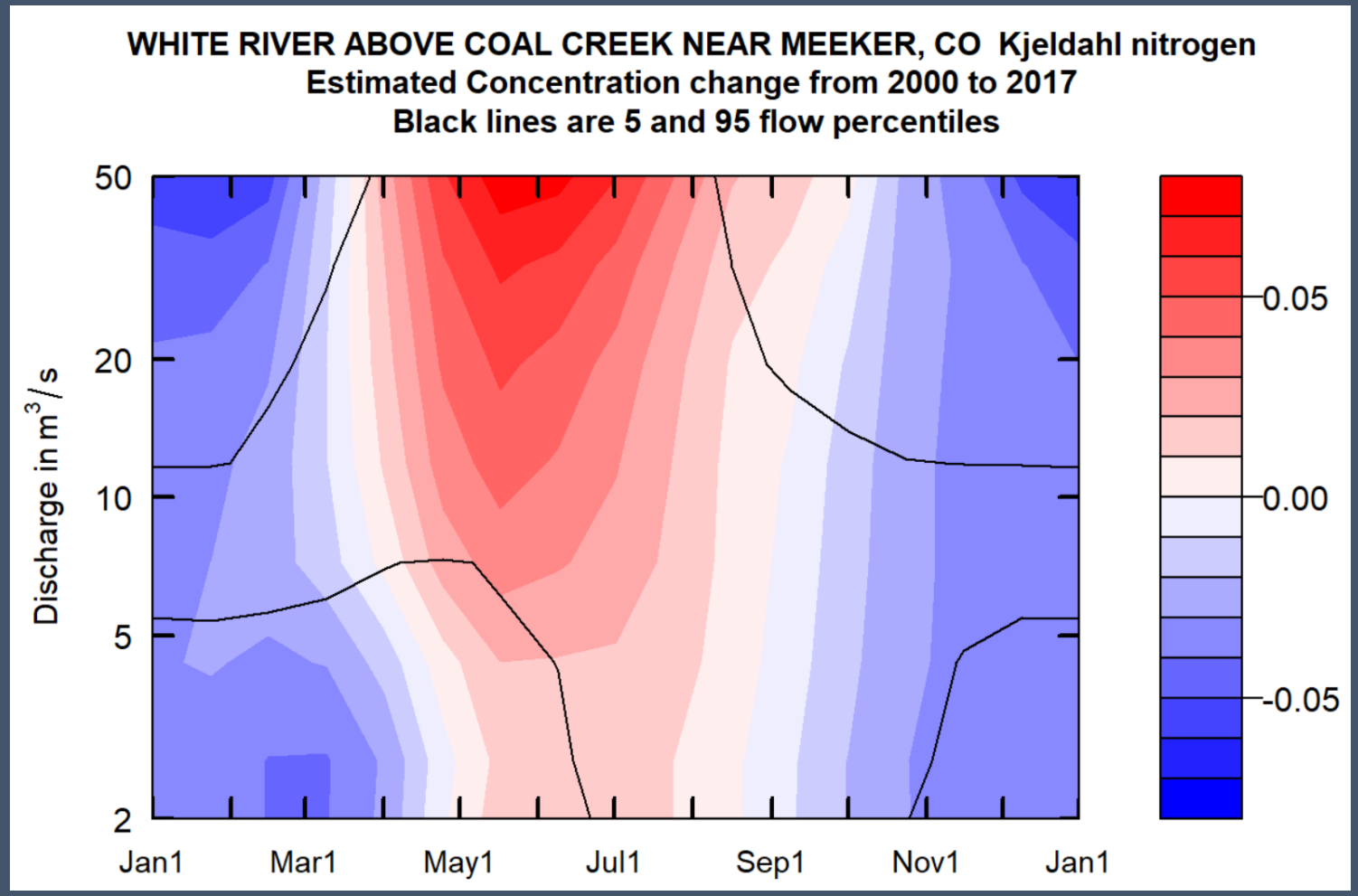
USGS
science for a changing world

Kjeldahl Nitrogen (Kjeldahl N) (Ammonia + Organic)

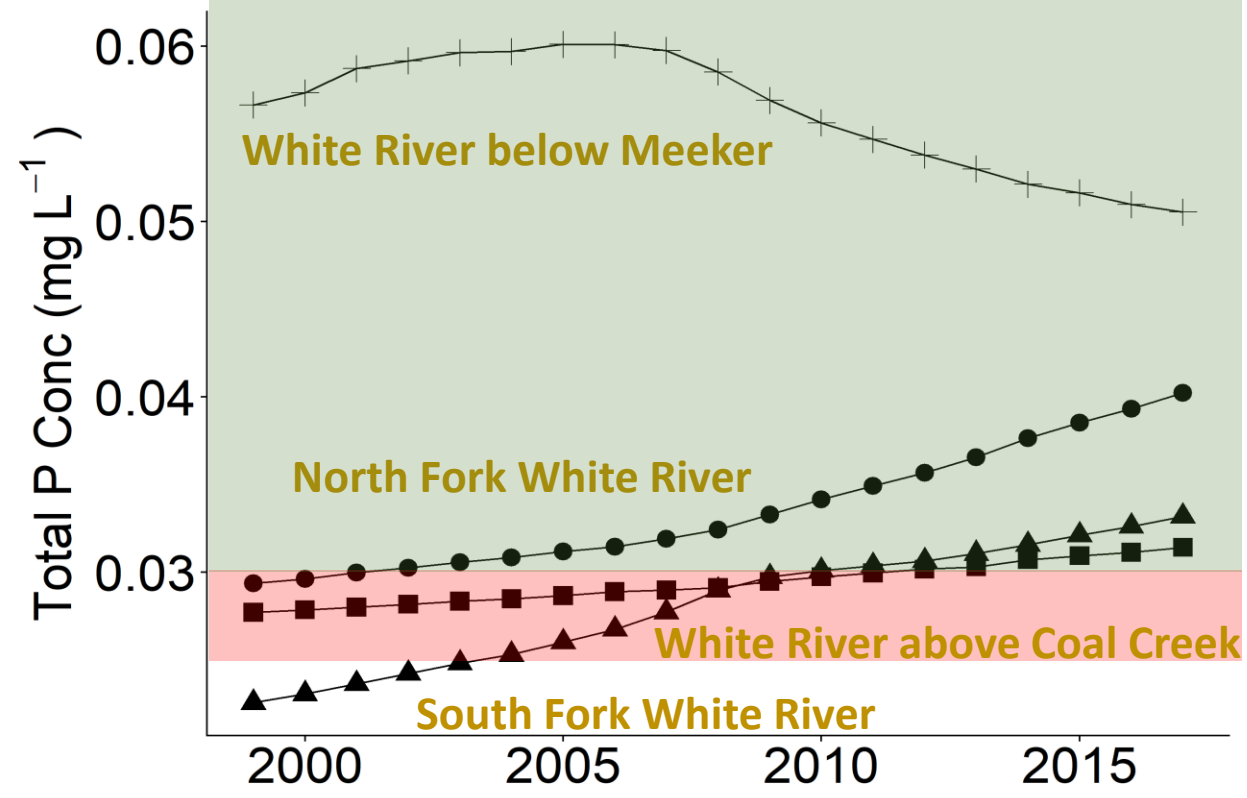


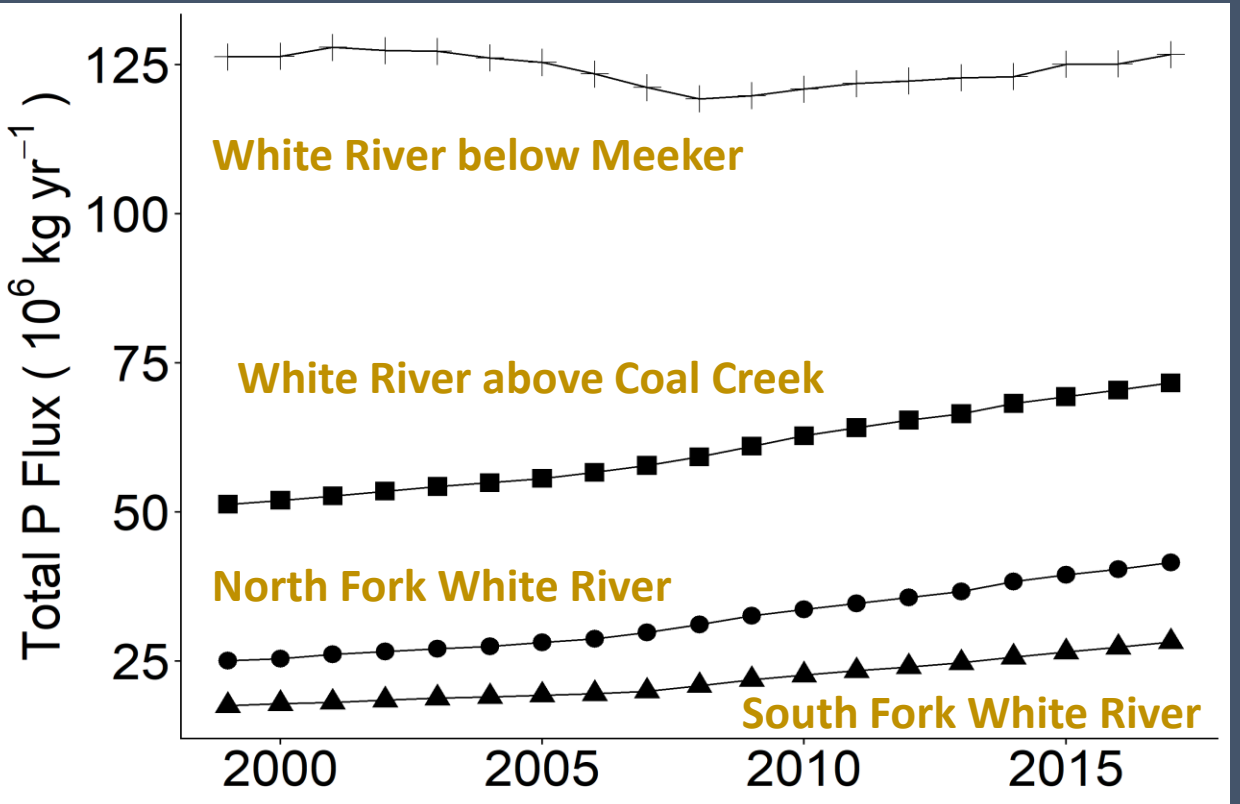
Site	Annual mean flow-normalized concentration in 2017, milligrams per liter	Change, 2000-2017		Annual mean flow-normalized flux in 2017, 10^6 kilograms per year	Change, 2000-2017	
		Milligrams per liter	%		Kilograms per year	%
North Fork White River at Buford	0.17	0.0089	0.33	0.059	0.0066	13
South Fork White River at Buford	15	0.016	12	0.040	0.0050	14
White River above Coal Creek	0.18	0.0015	0.79	0.12	0.014	13
White River below Meeker	0.28	-0.079	-22	0.20	-0.017	-7.7

Kjeldahl Nitrogen (Ammonia + Organic N)



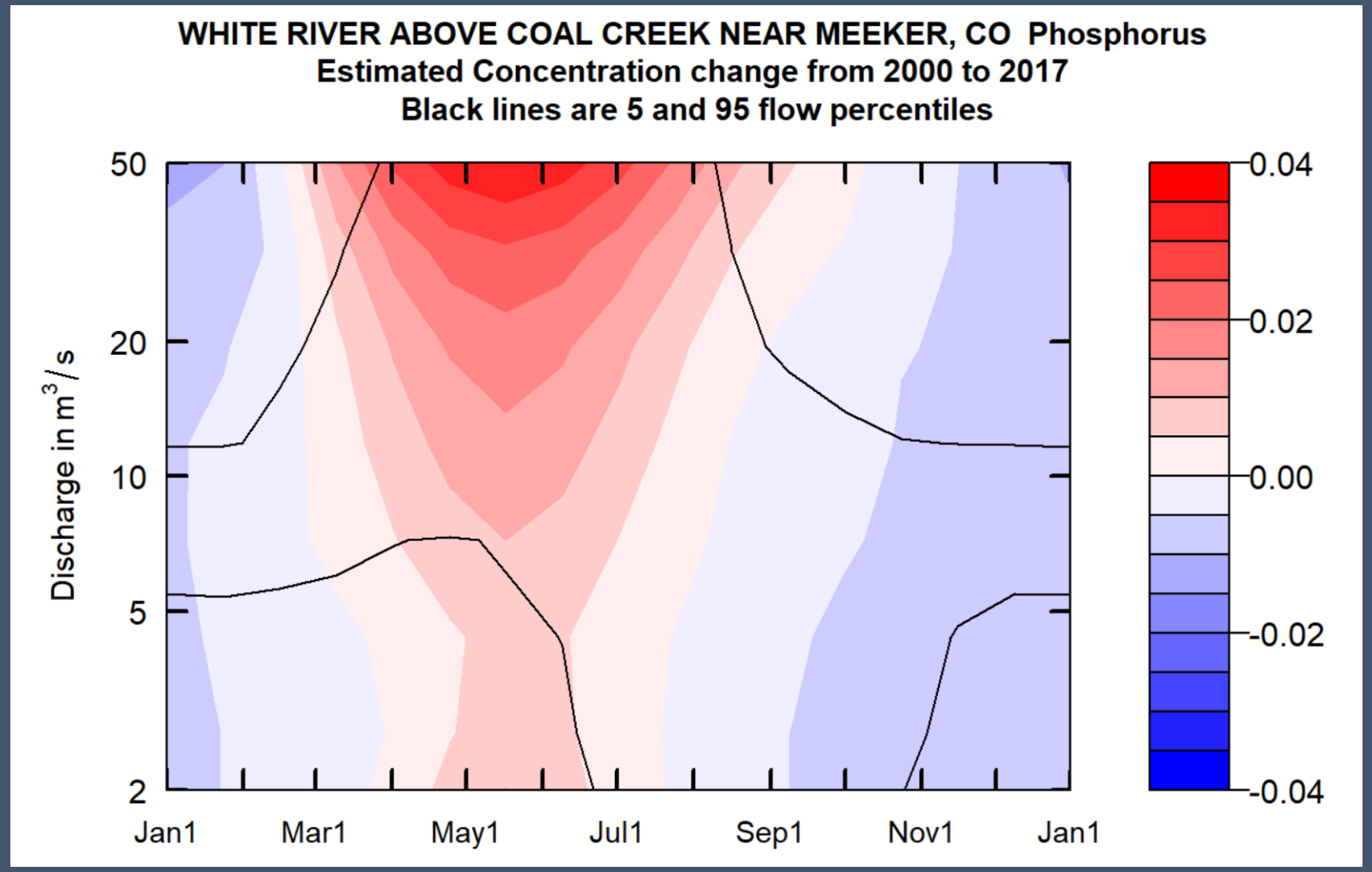
Total Phosphorus (Total P) (Organic plus Inorganic P)





Site	Annual mean flow-normalized concentration in 2017, milligrams per liter	Change, 2000-2017		Annual mean flow-normalized flux in 2017, 10^6 kilograms per year	Change, 2000-2017	
		Milligrams per liter	%		Kilograms per year	%
North Fork White River at Buford	0.040	0.01	35	0.015	0.006	64
South Fork White River at Buford	0.033	0.01	44	0.010	0.004	59
White River above Coal Creek	0.032	0.004	13	0.026	0.007	38
White River below Meeker	0.050	-0.006	-11	0.046	0.0004	0.77

Total Phosphorus (Organic plus Inorganic P)



Water-Quality Trends Summary

Kjeldahl Nitrogen

- Little to no change in annual concentration at White River above Coal and the tributaries (North Fork and South Fork White River)
- Approximately a 13% increase in flux at these sites
- Largest increase in concentration occurred during spring at high flows and decreases occurred during winter months

USGS
science for a changing world

Water-Quality Trends Summary

Total Phosphorus

- Substantial increases in concentration and flux at White River above Coal and the tributaries (North Fork and South Fork White River)
- Largest percent increases occurred in the tributaries
- Spring high flows show the greatest increase in Phosphorus concentrations

USGS
science for a changing world

Water-Quality Trends Interpretations

Understanding the timing of some patterns may provide clues to processes important to algae

- Trends in nutrients have been underway for decades
- Changes are occurring seasonally

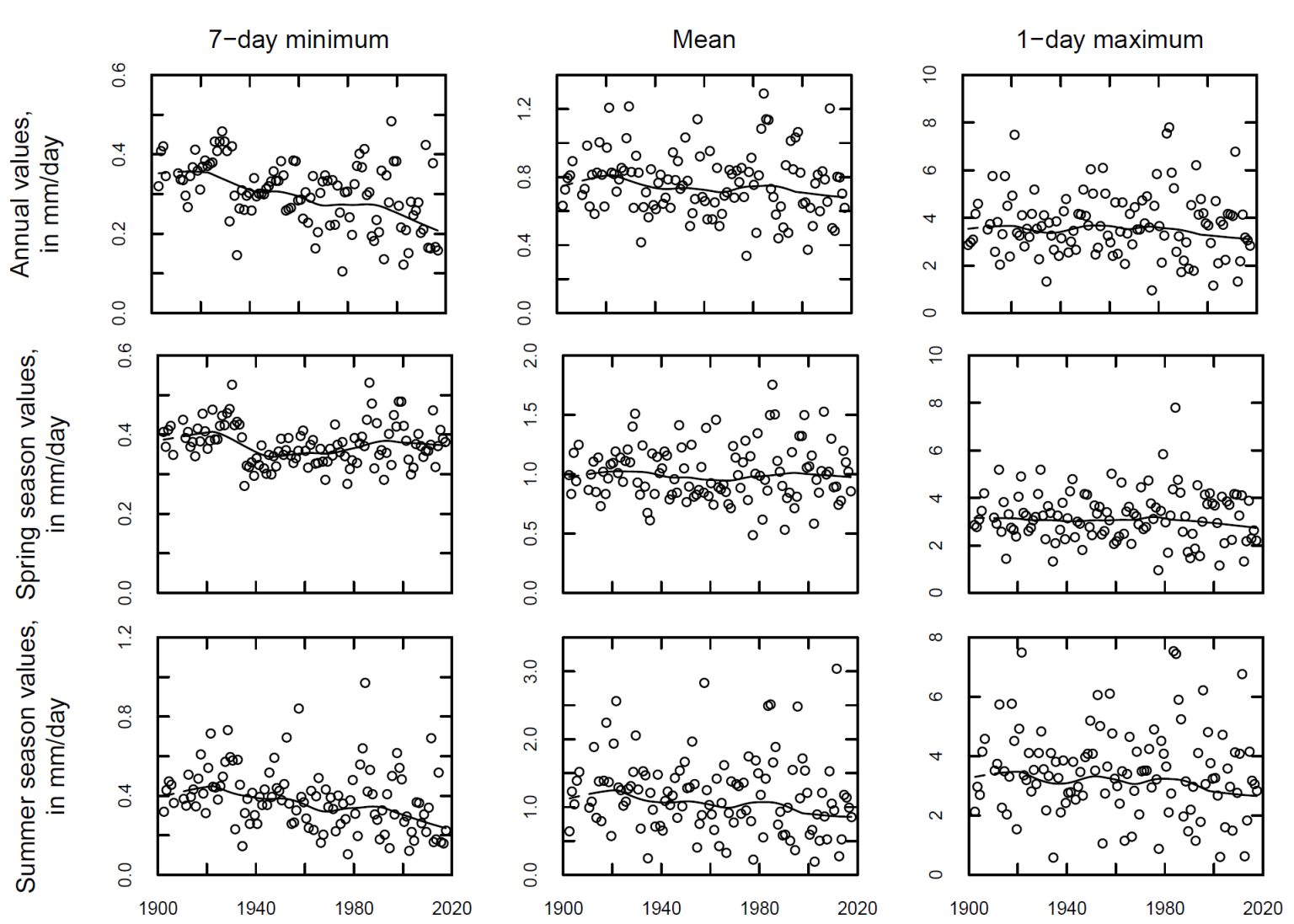
Understanding the magnitude of changes in conditions and spatial patterns may provide clues to processes important to algae

- Similar nutrient trends are occurring in both the North and South Forks
- Basin-wide patterns may be indicative of larger, regional changes of sources or processes
  - Trend-site locations do not fully constrain areas with changing land use patterns
- Comparisons of the magnitudes of trends may help key in on area that are most important to understanding algae

USGS
science for a changing world

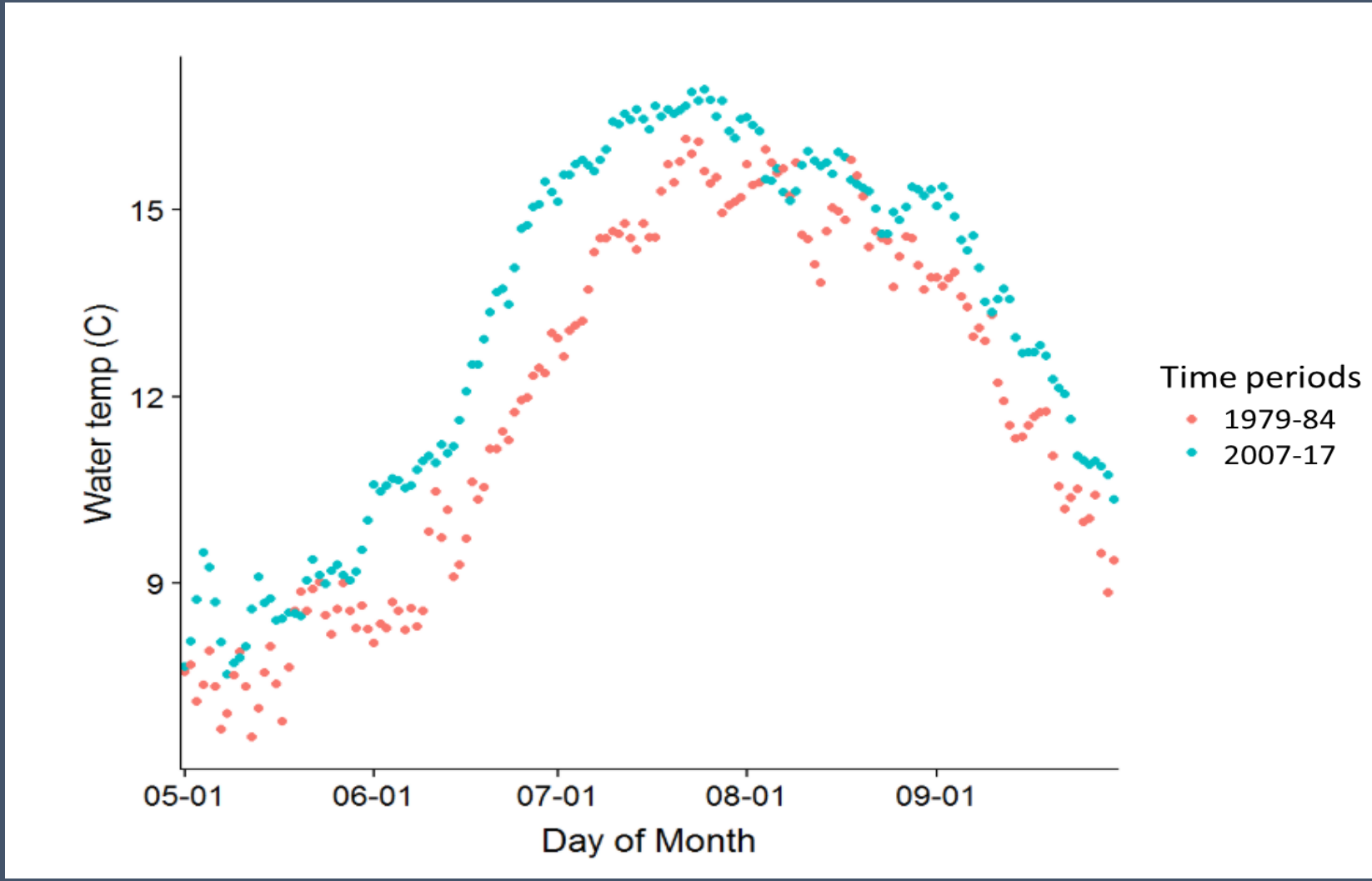
Historical Streamflow

White River near Meeker, CO



Historical Water Temperature

White River above Coal Creek



USGS
science for a changing world

Literature Review

- Expansion and inclusion of studies in other areas provide information that helps interpretation of White River data
  - Not all aspects of the problem can be addressed specifically by this study

    For example: Phosphorus levels are on the rise in many locations in the Western U.S.

- Initial review of journal articles and published materials is ongoing and continues to inform a conceptual model for algae in this basin

USGS
science for a changing world

Water Quality

- The first year of data were collected in 2018
  - Nutrient probe reconnaissance (map, used initially to scope sites)
  - Continuous water-quality monitoring

    - Continuous dissolved oxygen (DO)

    - Water temperature (WT)
  - Algae, chlorophyll-*a*/biomass
  - Water Isotope Sampling: Nitrogen and Oxygen of Nitrate molecule
- Data-collection intensifies next year (and continues beyond)
- Analysis continues early in 2019, and again in 2020-21
  - Statistical Analysis designed to assess this multi-year data set

USGS
science for a changing world

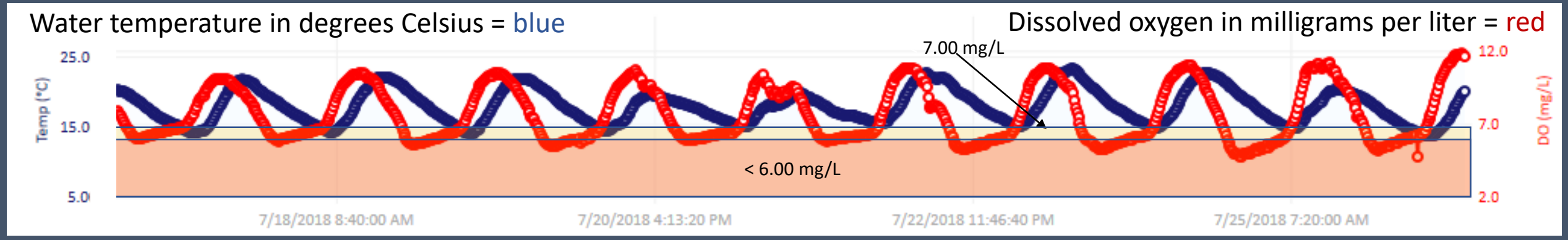
Nutrient Probe Reconnaissance

- May 2018 - Nitrate concentrations were measured at 10 selected locations along the White River in the study reach
  - Used to assess a preliminary distribution of nutrients along different reaches of the river
- Nitrate concentrations were consistently low at all locations
- Largest loads observed between confluence of North and South Forks and State of Colorado streamflow gage (Sleepy Cat)
- Highest concentrations observed in the North Fork near the Forest Service Boundary

USGS
science for a changing world

Continuous Water Quality 2018

- Changes in oxygen levels can be related to algal productivity, raising concentrations during the day, and consuming oxygen during the night
- Algal bloom die-off can also reduce dissolved oxygen
  - Low concentrations of oxygen can affect aquatic life
- Dissolved oxygen records were collected at all 19 sites, records are being corrected for calibration changes and quality assured this fall and winter



Continuous Water Quality 2018

- Dissolved Oxygen Observations:
  - Low-flow may exacerbate dissolved oxygen conditions
  - Large changes from day to night
  - Lowest concentrations and percent of saturation at night at most sites
  - Downstream sites tended to have lower concentrations
    - Influence of water temperature
    - Less re-aeration and slower velocity
  - Fish observed at most sites, no fish kills observed
  - Algal life-stage affects concentrations of Dissolved Oxygen and diel pattern

USGS
science for a changing world

Algae 2018

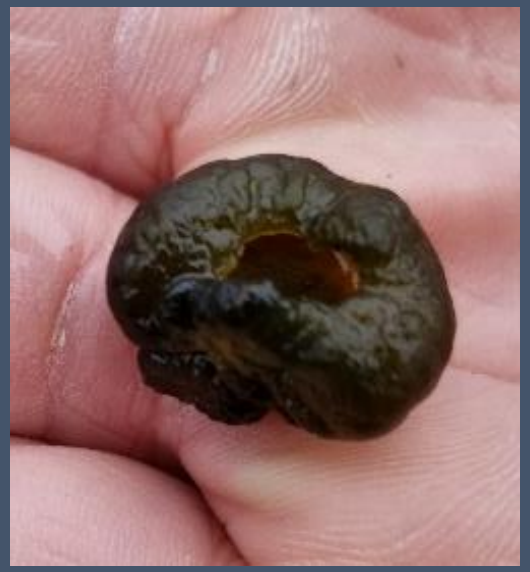
- Collected in association with continuous water-quality monitors
- Used to assess algae distribution and timing

Algal samples collected at 19 sites and analyzed at USGS lab

- Several types of algae present
- Variations along cross-section (bank to thalweg)
- All sites had Cladophora, even reference sites
- General trend - more algae at downstream sites
- Algal conditions were variable between sites, and at a site through time

USGS
science for a changing world

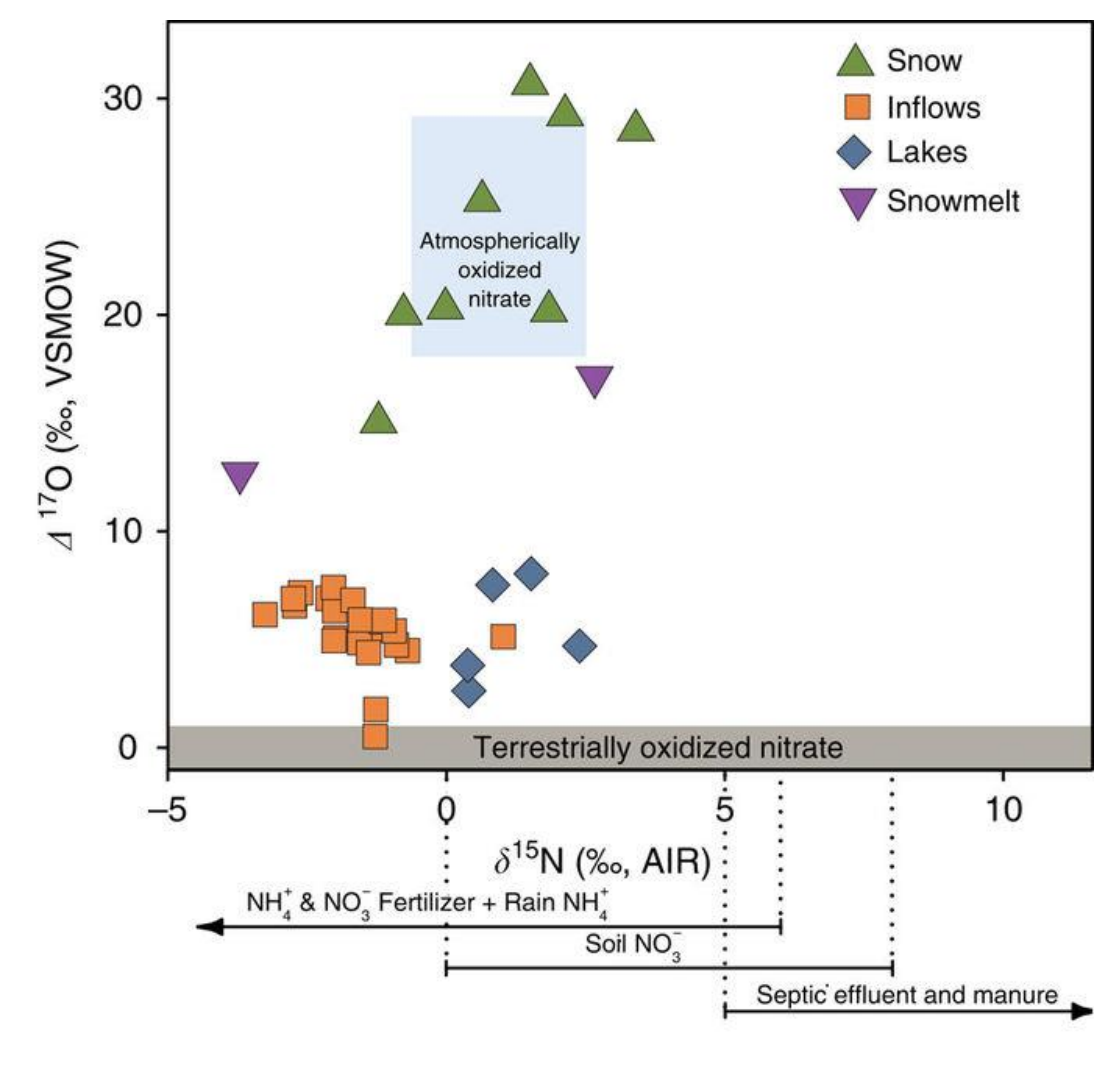
Algae Examples



USGS
science for a changing world

Nitrogen-Oxygen Isotopes of Nitrate

- Isotopes of Nitrogen and Oxygen in Nitrate may be used to identify sources of nutrients
- 2018 fieldwork
  - Isotope samples were collected and analyzed for nitrate concentrations at 6 locations
    - Concentrations were too low for isotope analysis
  - Sampling and nitrate analysis is ongoing
    - Exploring alternative sampling approaches to meet target concentration range



Hundey, E.J., Russell, S.D., Longstaffe, F.J., Moser, K.A., 2016, Agriculture causes nitrate fertilization of remote alpine lakes: N*ature Communications,* volume 7, Article number: 10571, 9p.

USGS science for a changing world

Next Steps

Current proposal for 2019 work plan tasks:

- Peak-flow data collection, scouring-flow analysis
- Water-quality sampling
- Algae sampling

Discussion of possible changes relevant to Water Year 2019 scope of work:

- Taxonomy (identification and quantification)
- Water temperature monitoring (non-telemetered data)
- Monitoring of algae during growing season (peak bloom varies by site)
  - Dissolved oxygen and temperature monitoring (telemetered data)
  - Photo-documentation of algal life stage (subset of sites)
  - Observers may assist with some of these additional tasks

USGS
science for a changing world

U.S. Geological Survey
Contact information

Mike Stevens
Hydrologist, Principal Investigator
mrsteven@usgs.gov

Natalie Day
Biologist, Coinvestigator
nkday@usgs.gov

Ken Leib
Western Colorado Office Chief
kjleib@usgs.gov

Cory Williams
Western Colorado Studies Chief
cawillia@usgs.gov

USGS
science for a changing world